XIII. *Obſervations on Reſpiration, and the Uſe of the Blood.* *By* Joſeph Prieſtley, *LL.D. F. R. S.*

R. Jan. 25, 1776. THERE is, perhaps, no ſubject in phyſiology, and very few in philoſophy in general, that has engaged more attention than that of the uſe of *reſpiration*. It is evident, that without breathing moſt animals would preſently die; and it is alſo well known, that the ſame air will not long anſwer the purpoſe: for if it has been frequently reſpired, the breathing of it is as fatal as the total deprivation of air. But by what property it is, that air contributes to the ſupport of animal life; and why air that has been much breathed will no more anſwer the purpoſe, ſeems not to have been diſcovered by any of the many philoſophers and phyſicians who have profeſſedly written upon the ſubject; and it might have continued to elude all *direct inveſtigation*, when it diſcovered itſelf, without any trouble or thought, in the courſe of my reſearches into the properties of different kinds of air, which had at firſt quite another object.

In theſe experiments it clearly appeared, that reſpiration is a *phlogiſtic proceſs*, affecting air in the very ſame manner as

as every other phlogiſtic proceſs (*viz.* putrefaction, the efferveſcence of iron-filings and brimſtone, or the calcination of metals, &c.) affects it; diminiſhing the quantity of it in a certain proportion, leſſening its ſpecific gravity, and rendering it unfit for reſpiration or inflammation, but leaving it in a ſtate capable of being reſtored to a tolerable degree of purity by agitation in water, &c. Having diſcovered this, I concluded, as may be ſeen Phil. Tranſ. vol. LXII. p. 187. and *Obſervations upon Air*, vol. I. p. 78. 277. that the uſe of the lungs is to carry off a putrid *effluvium*, or to diſcharge that phlogiſton, which had been taken into the ſyſtem with the aliment, and was become, as it were, *effete*; the air that is reſpired ſerving as a *menſtruum* for that purpoſe.

What I then concluded to be the uſe of *reſpiration* in general, I have now, I think, proved to be effected by means of the *blood*, in conſequence of its coming ſo nearly into contact with the air in the lungs; the blood appearing to be a fluid wonderfully formed to imbibe, and part with, that principle which the chemiſts call phlogiſton, and changing its colour in conſequence of being charged with it, or being freed from it; and affecting air in the very ſame manner, both out of the body and in the lungs; and even notwithſtanding the interpoſition of various ſubſtances, which prevent its coming into immediate contact with the air.

As it may not be unpleaſing or unuſeful, I ſhall, before I relate my own experiments, briefly recite the principal of the opinions which have been held con-

cerning the uſe of reſpiration, from HALLER'S excellent *Syſtem of Phyſiology*, and ſome others of the moſt eminent writers upon that ſubject.

HIPPOCRATES reckoned air among the *aliments* of the body. But it was more generally the opinion of the ancients, that, there being a kind of *vital fire* kept up in the heart, the heat of the blood was tempered in the lungs. GALEN alſo ſuppoſed, that there was ſomething equivalent to a fire conſtantly kept up in the heart; and that the chief uſe of the lungs was to carry off ſuch vapours as were equivalent to ſmoke thrown off from that fire. HALLER, vol. III. p. 354. CARTESIUS maintained the ſame vital fire in the heart, ſuppoſing that air was neceſſary for cooling and condenſing the blood. *Ibid.* p. 343.

Of the more modern phyſiologiſts, ſome have thought that the air itſelf is taken into the lungs; others, that it is only ſomething extracted from the air, as the more ſubtle parts of that fluid, an ether, or aerial nitre; while others ſuppoſe it to be the air itſelf, but diſſolved in water, and therefore in an unelaſtic ſtate, *ibid.* p. 321.

Moſt of thoſe who think that air is taken into the blood ſuppoſe it to be taken in by the lungs, *ibid.* p. 330. Some ſuppoſe, that the effect of the admiſſion of this air into the blood is a fermentation, p. 332. Others ſuppoſe, that it acts by its ſpring, preventing the too cloſe contact of the globules, and thereby preſerving its fluidity, inteſtine motion, and heat, *ibid.* BERTIER ſuppoſed, that the circulation of the blood was, in a great meaſure, owing to the admiſſion of air into it. VAN HELMONT aſcribed the volatility of the fixed elements

ments in the food to this air, p. 336.; and STEVENSON thought, that the air which had circulated in the blood, and which had heated the blood too much, was exhaled by the lungs, p. 355.

Others ſay, that the air itſelf is not admitted into the blood, but only ſome active, ſpirituous, and ethereal particles; that this vital ſpirit paſſes from the lungs to the heart and arteries, and at length becomes the animal ſpirits, which are by this means generated from the air, p. 333. Others, who do not admit that the animal ſpirits are derived from the air, ſtill ſay that ſome other *vital principle* comes from thence. This vital principle MALPIGHIUS ſuppoſes to be a ſaline vapour; LISTER, a hot, inflammable, ſulphureous ſpirit; VIEUSSENIUS, a volatile acid ſalt, which keeps up the fermentation of the blood; and BRYAN ROBINSON, the aerial acid, which preſerves the blood from putrefaction; preſerves alſo its denſity, and ſtrengthens the animal fibres. For this reaſon he ſuppoſes it is that we feel ourſelves refreſhed in cold air, as it abounds with a more plentiful acid quality, p. 334. They who ſuppoſe that nitre is taken from the air into the blood, aſcribe to that principle its fermentation, its heat, and its denſity, p. 334.

It is a received opinion, that one uſe of the lungs is to attenuate the blood, p. 359; and MALPIGHIUS adds, that by this means, the different particles of the blood become thoroughly mixed together; while others think that the blood is condenſed in the lungs; and others, that the globules, and all the finer humours, receive their configuration there, *ibid.* Some, without conſidering the air

air as of any other uſe than to put the lungs in motion, think, that heat is produced in the lungs by the attrition of the blood in paſſing through them .*Miſc. Taurin.* vol. V. p. 36. The red colour of the blood has been thought by ſome to be cauſed by this attrition in the lungs; but LOWER refuted this notion, chiefly by obſerving, that the attrition of the blood is greater in the muſcles, from which, however, it always returns black, *Ibid.* vol. I. p. 74.

Dr. WHYTT thought there was ſomething of a vital and ſtimulating nature derived from the air into the blood, by means of which it made the heart to contract, HALLER, vol. III. p. 336.

BOERHAAVE ſays, that air not changed is deadly; not on account of heat, rarefaction, or denſity, but for ſome other occult cauſe. *Miſc. Taurin.* vol. V. p. 30.

Dr. HALES, who has thrown much more light upon the doctrine of air than all his predeceſſors, was equally ignorant of the uſe of it in reſpiration; and at different times ſeems to have adopted different opinions concerning it.

In his *Statical Eſſays*, vol. II. p. 321. he ſuppoſes, that air is rendered alcaline by breathing, and corrected, in ſome meaſure, by the fumes of vinegar.

In agreement, as he obſerves, with BOERHAAVE, he ſays, p. 100. that the blood acquires its warmth chiefly in the lungs, where it moves with much greater rapidity than in any other capillary veſſels of the body, vol. II. p. 87; but that one uſe of the air is to cool the blood, p. 94; and he makes an eſtimate of the degree of this refrigeration. The red colour of the globules of blood, he ſays, p. 88,

intimates

intimates their abounding with ſulphur, which makes them more ſuſceptible and retentive of heat than thoſe bodies which have leſs of it.

He alſo ſuppoſes, p. 102, that another great uſe of the lungs is to attenuate and ſeparate the globules of blood; and that the floridneſs of the arterial blood above the venal may, in a good meaſure, be owing to the ſtrong agitation, friction, and comminution, which it undergoes in paſſing through them. In like manner, in an experiment which he made for the purpoſe, blood much agitated in a cloſe glaſs veſſel was obſerved to be very florid, not only on its ſurface, but through its whole ſubſtance, as arterial blood is, vol. II. p. 102. I would obſerve, however, that in this expement, the blood muſt have acquired its florid colour from the air with which it was agitated.

He adds, that it is probable, that the blood may, in the lungs, receive ſome other important influence from the air, which is in ſuch great quantities inſpired into them. In other places, however, he explodes the doctrine of a *vivifying ſpirit* in the air. It has long, he ſays, been the ſubject of inquiry to many, to find of what uſe it is in reſpiration; which, though it may in ſome reſpects be known, yet it muſt be confeſſed, that we are ſtill much in the dark about it, vol. II. p. 102.

Suffocation, he ſays, vol. II. p. 271. conſiſts chiefly in the falling flat of the lungs, occaſioned by the groſſneſs of the particles of a thick noxious air, they being, in that floating ſtate, moſt eaſily attracted by each other, as we find that ſulphur, and the elaſtic repelling particles of air are;

and conſequently unelaſtic, ſulphureous, ſaline, and other floating particles, will moſt eaſily coaleſce, whereby they are rendered too groſs to enter the minute veſicles, which are alſo much contracted, as well by the loſs of the elaſticity of the confined air, as by the contraction occaſioned by the ſtimulating acid ſulphureous vapours. And hence it is not improbable, that one great deſign of nature in the ſtructure of this important and wonderful *viſcus*, was to frame the veſicles ſo very minute, thereby effectually to hinder the ingreſs of groſs, feculent particles, which might be injurious to the animal economy.

Laſtly, he concludes, that the effect of reſpiration is to abate, and in part deſtroy, the elaſticity of the air; and as this was effected by ſuphureous vapours, and he could breathe for a longer time air that had paſſed through cloaths dipped in a ſolution of ſalt of tartar, he concluded, that the air had been mended by the tartar having ſtrongly imbibed the ſulphureous, acid, and watery vapours, vol. I. p. 267.

HALLER, after reciting the opinions of all that had gone before him, ſuppoſes, with Dr. HALES, that, in conſequence of the air loſing its ſpring in the lungs, they cannot be kept dilated; and therefore, they muſt collapſe, and the circulation of the blood be impeded, vol. III. p. 258. When he ſtates his opinion concerning the uſe of the lungs more fully, he ſays, that the true uſe of them is partly inhaling, and partly exhaling, p. 351. That the lungs inhale both water and air; but that in the lungs the air loſes its elaſtic property, ſo as to be eaſily ſoluble in water or vapour, p. 352.: and he thinks it probable,

probable, that this air ſerves as a cement to bind the earthy parts together. He alſo makes no doubt, but that various other matters, miſcible with water, are inhaled by the lungs; and he even thinks it not improbable, that the air may carry ſome electric virtue along with it. The principal exhalation of the lungs, he thinks, to be water, abounding with oily, volatile, and ſaline principles; and theſe oily and fetid vapours, he thinks, to be the *fuligines* of GALEN and other ancients, p. 354.

Mr. CIGNA of Turin, has given much attention to this curious ſubject, as appears by two Memoirs of his; one in the firſt volume of the *Miſcellanea Taurinenſia*, in which he very well accounts for the florid red colour of the blood; and the other, which is a much more elaborate Memoir, intitled, *De Reſpiratione*, in the fifth volume of the ſame work, juſt publiſhed, or about to be publiſhed, the copy of the article having been ſent to me by the author.

He takes it for granted, that air which has once been breathed is unfit for farther reſpiration, on no other account than its being loaded with *noxious vapours*, which diſcover themſelves by a fetid ſmell. *Miſc. Taurin.* vol. V. p. 30. And he takes it for granted, that the elaſticity of air is diminiſhed by reſpiration, though he does not conſider that diminution of elaſticity as the cauſe of its noxious quality. He therefore concludes, that air which has been breathed, ſuffocates by means of the irritation which it occaſions to the lungs, by which the bronchia, and the lungs themſelves, are contracted, ſo as to reſiſt the entrance of the air; and therefore, that reſpired air is

noxious on the ſame account as mephitic vapours, or thoſe of burning brimſtone, p. 31; that, in frequently breathing the ſame air, it becomes ſo loaded with theſe vapours, as to excite a convulſion in the lungs, and thereby render them unfit for tranſmitting the blood, p. 42.

This philoſopher ſuppoſes that air enters the pores of the blood, retaining its elaſtic power, p. 50. and that it continues at reſt there, becauſe its endeavour to eſcape is counteracted by the equal preſſure of the ambient medium, p. 52. This air, he ſuppoſes to be introduced into the blood by the chyle, and never by the way of the lungs, except when, by ſome means or other, the equilibrium between the air in the blood and the external air is loſt, p. 57. If the external air be rarer than the internal, the air in the blood, expanding itſelf, will inflate the animal, and have the ſame effect as air introduced into the veins.

What we are chiefly indebted to M. CIGNA for, is his deciſive experiments with reſpect to the florid colour of the blood, which he clearly proves to be cauſed by the contact of air; though he afterwards ſeems willing to deſert that hypotheſis. It was often imagined, that the reaſon why the lower part of a quantity of blood was black, while the ſurface was red, was, that the black particles, being heavier than the reſt, ſubſided to the bottom; but this opinion our author clearly refutes. He found, that when he put a little oil upon a quantity of blood, it remained black throughout; but that when he took away the red part, and expoſed to the air the lower

laminæ,

laminæ, which were black, they alſo became ſucceſſively red, till the whole maſs acquired that colour, *Miſc. Taurin.* vol. I. p. 73. Alſo, at the requeſt of M. CIGNA, Father BECCARIA tried what would be the effect of expoſing blood in *vacuo*; and he found, that in thoſe circumſtances, it always continued black; but that, by expoſing it again to the air, it became red, p. 68.

M. CIGNA concludes his firſt diſſertation with obſerving, that it is not eaſy to ſay how it comes to paſs, that the lower part of a maſs of blood becomes black, whether by the air which it had imbibed eſcaping from it, or by its depoſiting ſomething ſaline, neceſſary to contribute to its redneſs, or by the preſſure of the atmoſphere; but he inclines to think, that air mixed with blood, and interpoſed between the globules, preſerves its redneſs: but that by concreting it is expelled from it, or becomes ſo fixed as to be incapable of making it red. This opinion, he thinks, is rendered in ſome meaſure probable, by the increaſed denſity of concreted blood, and by the emiſſion of air from other fluids in a concreſcent ſtate, p. 74.

Notwithſtanding what he had advanced in his firſt Memoir, yet in the ſecond, which was written ſeveral years after it, he doubts whether the change of colour in the blood takes place in the lungs; but if it does, he inclines to aſcribe this effect to the *evaporation* from the blood in the lungs: and though he always found, that the colour of the blood was changed by the contact of air, yet when he conſidered that evaporation muſt, as he thought, neceſſarily attend the contact of air, he imagined, that this

effect might equally be attributed to this circumſtance. But he acknowledges, that this hypotheſis ought not to be received till it be confirmed by experiments, *Miſc. Taurin.* vol. V. p. 61.

Upon the whole, he concludes, that the principal uſe of air to the *blood*, is to preſerve the equilibrium with the external air, and to prevent the veſſels from being rendered unfit to tranſmit the blood, on account of the external preſſure; whereas, by means of the air they contain, the fluids move in their proper veſſels as freely as in *vacuo*, and the membranes and viſcera alſo eaſily ſlide over each other, p. 63. And with reſpect to the uſe of the *lungs*, ſince he imagined that air is not introduced into the blood by means of them, he thinks, that becauſe ſuch lungs as thoſe of man are given to the warmer animals only, the chief uſe of reſpiration is exhalation, and conſequently the cooling of the blood, p. 65.

The laſt writer whom I ſhall quote upon this ſubject, is the late ingenious Mr. HEWSON; who ſays, in his *Experimental Inquiry into the Properties of Blood*, p. 9. "As the colour of the blood is changed by air out of the "body, it is preſumed, that the air in the lungs is the "immediate cauſe of the ſame change in the body." That this change is really produced in the lungs, he is perſuaded, he ſays, from experiments, in which he diſtinctly ſaw the blood of a more florid red in the left auricle of the heart than it was in the right; but how this effect is produced, he ſays, is not yet determined.

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Since ſome of the neutral ſalts, and particularly nitre, has a ſimilar effect on the colour of the blood; ſome, ſays he, attribute this difference to the nitre abſorbed from the air, while in the lungs. But this, he adds, is a mere hypotheſis, for air contains no nitre, and moſt of the neutral ſalts produce the ſame effect in ſome degree.

Since, however, a ſolution of nitre does produce this effect upon blood, inſtantly making the very blackeſt of it of a beautiful florid red, though this effect is not peculiar to nitre (for a ſolution of common ſalt does nearly the ſame thing) I own I am inclined to aſcribe this effect to the air; eſpecially ſince I have proved, as I apprehend, that atmoſpherical air conſiſts of earth and ſpirit of nitre. Poſſibly, therefore, the air we breathe may be ſo far decompoſed, as to communicate ſomething of nitre to the blood, in its paſſage through the lungs.

After this review of the obſervations and opinions of others on this important queſtion in phyſiology, I ſhall proceed to recite my own. It may appear ſomething extraordinary, that among ſuch a variety of opinions concerning the uſe of reſpiration, the right one ſhould never have been ſo much as conjectured, though unſupported by the proper proof. But indeed, this animal function, and the phlogiſtic proceſſes in chemiſtry, eſpecially that of the calcination of metals, which is, perhaps, the moſt ſimple of them, are to appearance very different things; and therefore, it is the leſs to be wondered, that no perſon ſhould

ſhould have imagined, they would produce the ſame effect on the air in which they were performed.

That reſpiration, however, is, in reality, a true phlogiſtic proceſs, cannot, I think, admit of a doubt, after its being found, that the air which has ſerved for this purpoſe is left in preciſely the ſame ſtate as that which has been expoſed to any other phlogiſtic proceſs. And ſince all the blood in the body paſſes through the lungs, and, according to Mr. HEWSON'S obſervations and others, the remarkable change between the colour of the venal and arterial blood takes place there, it can hardly be doubted, that it is by means of the *blood* that the air becomes phlogiſticated in paſſing through the lungs; and therefore, that one great uſe of the blood muſt be to diſcharge the phlogiſton with which the animal ſyſtem abounds, imbibing it in the courſe of its circulation, and imparting it to the air, with which it is nearly brought into contact, in the lungs; the air thus acting as the great menſtruum for this purpoſe.

Though I had no doubt concerning this concluſion from my former experiments, I thought ſo great a problem deſerved as much illuſtration as could be given to it; and therefore I was willing to try, whether the blood was of ſuch a nature, as to retain any of this power of affecting air when congealed, and out of the body, that it has when it is fluid, and in the body; and the experiments have fully anſwered my expectations.

Having taken the blood of a ſheep, and let it ſtand till it was coagulated, and the ſerum was ſeparated from it (after which the ſurface, being expoſed to the common

air, is well known to aſſume a florid red colour, while the inſide is of a much darker red, bordering upon black) I introduced pieces of the craſſamentum, contained in nets of open gauze, or of wire, ſometimes through water, and ſometimes through quickſilver, into different kinds of air, and always found that the blackeſt parts aſſumed a florid red colour in common air, and more eſpecially in dephlogiſticated air, which is purer and more fit for reſpiration than common air (and accordingly the blood always acquired a more florid colour, and the change was produced in leſs time in this than in common air) whereas the brighteſt red blood became preſently black in any kind of air that was unfit for reſpiration, as in fixed air, inflammable air, nitrous air, or phlogiſticated air; and after becoming black in the laſt of theſe kinds of air, it regained its red colour upon being again expoſed to common air, or dephlogiſticated air; the ſame pieces becoming alternately black and red, by being transferred from phlogiſticated to dephlogiſticated air; and *vice verſâ*.

In theſe experiments the blood muſt have parted with its phlogiſton to the common air, or dephlogiſticated air, and have imbibed it, and have become ſaturated with it, when expoſed to phlogiſticated, nitrous, inflammable, or fixed air. The only difficulty is with reſpect to the fixed air; for all the other kinds certainly contain phlogiſton. But, as I have obſerved in the account of my experiments on vitriolic acid air, phlogiſton ſeems to be neceſſary to the conſtitution of every kind of air; and beſides, the blackneſs of the blood may ariſe from other cauſes than

than its acquiring phlogiſton. GABER, for inſtance, obſerves, that blood becomes black when it begins to putrify, as it does alſo whenever it is dried and hardened near the fire. Father BECCARIA alſo found, as I have obſerved, that red blood *continued* (and he could hardly fail to obſerve alſo, that it *became*) black in *vacuo*, where it could not have imbibed phlogiſton. This I found to be the caſe when the blood was covered two inches and a half with ſerum; but it regained its florid colour when it was expoſed to the open air.

In general, however, it cannot be expected, that when blood has become black without having received phlogiſton *ab extra*, it will recover its florid colour by being expoſed to the air. For the delicacy of its texture, and conſequently its capacity of being eaſily affected by phlogiſton, may be eſſentially altered by internal cauſes of blackneſs. This is even the caſe when blood has become black by being expoſed to nitrous and inflammable air, though this change is probably effected by its imbibing phlogiſton.

I expoſed pieces of the ſame maſs of red blood to theſe two kinds of air, and alſo to fixed air at the ſame time. They all became black; but that which was in the inflammable air was the leaſt ſo, and none of them recovered their florid colour in the open air. But at another time, a piece of craſſamentum, which had become black in fixed air, did, in ſome meaſure, and very ſlowly, recover its florid colour in dephlogiſticated air. Perhaps the pieces that had loſt their colour in the nitrous and inflam-

inflammable air might have recovered it by means of this more powerful menſtruum.

Since, however, blood, after becoming black in phlogiſticated air, is always capable of reſuming its red colour on being again expoſed to pure air, it may be concluded, that the preceding blackneſs, diſcharged in the pure air, and producing the conſtant effect of phlogiſton, in depraving the air, was owing to the phlogiſton it had imbibed in the former ſituation, and which it parted with in the latter. And this is remarkably the caſe when blood is transferred from phlogiſticated into dephlogiſticated air. Even the circumſtance of the *deeper colour* is ſufficient to give a chemiſt a ſuſpicion that it contains more phlogiſton than blood of a lighter colour.

When I had found how readily pieces of blood changed their colour, according to the quality of the air to which they were expoſed, I proceeded to examine the ſtate of that air, in order to obſerve what change had taken place in it; and as dephlogiſticated air admits of a more ſenſible change of quality than common air, I gave it the preference in this experiment; putting a piece of craſſamentum, about the bigneſs of a walnut, into the quantity of about five ounce meaſures of this air.

This proceſs I continued for the ſpace of twenty-four hours, changing the blood about ten or twelve times; after which I found the air ſo far depraved, that whereas, at the beginning of the experiment, one meaſure of it and two of nitrous air occupied the ſpace of no more than half a meaſure, the ſame mixtures afterwards occupied

the ſpace of a meaſure and a half. Now ſince air is univerſally depraved by phlogiſton, and in this ſenſe, I believe, by nothing elſe, it is evident, that this black blood muſt have communicated phlogiſton to the air; and conſequently its change of colour from black to a florid red muſt have been occaſioned by the ſeparation of phlogiſton from it.

The next day, when, of courſe, the blood was nearer to a ſtate of putrefaction, in which every kind of ſubſtance, without exception, will injure reſpirable air, I put a quantity of red blood, tinged in a few places with black, which I could not eaſily ſeparate from it, to about the ſame quantity of the ſame dephlogiſticated air, and ſuffered it to ſtand, without changing, for the ſame ſpace of time; when it was ſo little injured, that the meaſures abovementioned occupied the ſpace of only two-thirds of a meaſure.

That blood has a power of taking phlogiſton from air, as well as imparting phlogiſton to air, I ſatisfied myſelf by expoſing blood of a very beautiful florid colour to nitrous air, inflammable air, and phlogiſticated air. The two firſt mentioned kinds of air were conſiderably diminiſhed by the proceſs, which was continued two days, during which time the blood had been changed five or ſix times.

The nitrous air, by this means, loſt a great proportion of its power of diminiſhing, that is, phlogiſticating, oommon air. For now two meaſures of common air and cne of this occupied the ſpace of $2\frac{1}{4}$, inſtead of $1\frac{3}{4}$ meaſures. The inflammable air, though ſtill inflammable,

was rendered in ſome degree wholeſome by the proceſs; being, after this, conſiderably diminiſhed by nitrous air, which is a ſtate to which it is brought by agitation in water, and which, continued longer, deprives it of its inflammability likewiſe. It cannot be doubted, therefore, but that, in both theſe caſes, the red blood, by becoming black, received phlogiſton from theſe two kinds of air.

With reſpect to the phlogiſticated air, I only obſerved that, after a few hours expoſure to the red blood, it was ſenſibly, but not much, diminiſhed by nitrous air, which otherwiſe it would not have been in the leaſt degree. This blood, however, was of the lighteſt colour; that is, according to my hypotheſis, the moſt free from phlogiſton, of any that I have ever ſeen; and I have tried the ſame thing, without ſucceſs, with blood of a leſs florid colour, though as florid as the common air could make it. But it ſhould be conſidered, that the proper function of the blood is not to receive phlogiſton from *air*, not meeting with any phlogiſticated air in the courſe of its circulation, but to communicate phlogiſton to air; and therefore, there is by no means the ſame reaſon to expect, that air will be mended by red blood, as that it will be injured by black blood.

It may be objected to this hypotheſis, concerning the uſe of the blood, that it never comes into actual contact with the air in the lungs, but is ſeparated from it, though as Dr. HALES ſtates it, at the diſtance of no more than a thouſandth part of an inch. The red globules alſo ſwim

in a large quantity of ſerum, which is a fluid of a quite different nature.

In order to aſcertain the effect of theſe circumſtances, I took a large quantity of black blood, and put it into a bladder moiſtened with a little ſerum, and tying it very cloſe, hung it in a free expoſure to the air, though in a quieſcent ſtate; and the next day I found, upon examination, that all the lower ſurface of the blood, which had been ſeparated from the common air by the intervention of the bladder (which is an animal membrane, ſimilar to that which conſtitutes the veſicles of the lungs, and is at leaſt as thick) and likewiſe a little ſerum, had acquired a coating of a florid red colour, and as thick, I believe, as it would have acquired, if it had been immediately expoſed to the open air; ſo that this membrane had been no impediment to the action of the air upon the blood. In this caſe it is evident to obſerve, that the change of colour could not be owing to *evaporation*, as Mr. CIGNA conjectures. This experiment I repeated, without previouſly moiſtening the bladder, and with the very ſame reſult.

I obſerved alſo, that when I cut out a piece of the craſſamentum, and left the remainder in the veſſel with the *ſerum*, not only that part of the ſurface which was expoſed to the air, but that which was ſurrounded with *ſerum*, and even covered with it to the depth of ſeveral inches, acquired the florid colour; ſo that this deep covering of ſerum, which muſt have effectually prevented all evaporation, was no more an impediment to the mutual action of the blood and the air, than the bladder had been.

been. The ſerum of the blood, therefore, appears to be as wonderfully adapted to anſwer its purpoſe, of a vehicle for the red globules, as the red globules themſelves: for the ſlighteſt covering of water, or *ſaliva*, effectually prevents the blood from acquiring its florid colour; and Mr. CIGNA found that this was the caſe when it was covered with oil.

That it is really the air, acting through the ſerum, and not the ſerum itſelf, that gives the florid colour to the blood, is clearly aſcertained by the following experiment. I took two equal portions of black blood, and put them into equal cups, containing equal quantities of ſerum, which covered them to the depth of half an inch. One of theſe cups ſtanding in the open air, and the other being placed under an exhauſted receiver, the former preſently acquired a florid colour, while the other continued twelve hours as black as at firſt. Being taken out of the receiver, it ſtood all night in the open air without becoming red, and continued black ever after, even when the ſerum was poured off.

I alſo more completely ſatisfied myſelf of the influence of the air upon the blood, through a body of ſerum, by the reverſe of this experiment. For I found that red blood became black through the depth of two inches of ſerum, when the veſſel containing it was expoſed to phlogiſticated air; ſo that the red globules of the blood both receive, and part with phlogiſton by means of the air, notwithſtanding the interpoſition of a large body of the fluid in which they naturally float.

Except

Except ſerum, *milk* is the only animal fluid that I have tried, through which the air can act upon blood: for black blood became red when it was plunged in milk, in the ſame manner as if it had been covered with ſerum. In urine, indeed, black blood becomes inſtantly red; but this is not owing to the action of the air, through the urine, but to the ſaline nature of that fluid.

In ſome caſes, care muſt be taken to diſtinguiſh the floridneſs with which ſome detached parts of a quantity of blood are tinged, from that which penetrates the ſolid parts of it. In *ſaliva*, and in water impregnated with alkaline ſalt, fixed or volatile, and alſo in ſpirit of wine, the extreme angles and edges of pieces of craſſamentum and ſmall detached parts, floating in thoſe liquors, will appear of a very florid red, while the compact maſs of blood continues dark. The florid colour of the prominent and detached parts, in theſe caſes, ſeems to be the mere effect of the minute diviſion of the parts of the craſſamentum in the fluid in which thoſe parts float; when at the ſame time it has no ſuch effect on thoſe parts which remain compact, nor has the air the leaſt power of acting on the blood through the liquor.

I had imagined, that ſince black blood contains more phlogiſton than red blood, that difference would have appeared in the *air* produced from them, either by being ſimply diſſolved in ſpirit of nitre, or when dried and made into a paſte with that acid. But the difference was too ſmall to be ſenſible to this kind of teſt. For this purpoſe, however, I had ſome blood drawn from the vein

of

of a ſheep, and alſo took ſome that came firſt after killing it, as the butchers uſually do, by dividing the *carotid* artery; but though I diſſolved the black part of the former, and the red part of the latter, in equal quantities of the ſame ſpirit of nitre, I found no ſenſible difference in the air that they yielded. The air that I got from them when dried, and made into a paſte with ſpirit of nitre, was likewiſe equally indiſtinguiſhable. The quantity of air from this proceſs was very great, and was produced irregularly, as I have obſerved it to have been when produced by a ſolution in ſpirit of nitre without drying. *Obſervations on Air*, vol. II. p. 155. Half of this produce was fixed air, and the reſt phlogiſticated, except that a candle burned in it with a lambent blue flame. It is evident, however, from this experiment, that even the moſt florid blood contains a conſiderable quantity of phlogiſton; for, otherwiſe, this air would have been dephlogiſticated.

I would conclude this paper with obſerving, that I have found a very great difference in the conſtitution of blood with reſpect to its property of being affected by the influence of the air; ſome becoming very ſoon of a light florid colour, and the *ſtratum* of this colour ſoon growing very thick; whereas, in other caſes, the colour of the blood, in the moſt favourable circumſtances, has continued much darker, and the lighter colour has never penetrated very far.

As the principal uſe of the blood ſeems to be its power of receiving and diſcharging phlogiſton, and the degree in

in which it poſſeſſes this power is eaſily aſcertained by the eye, it might not, perhaps, be unworthy of being particularly attended to by phyſicians. To eſtimate the goodneſs of blood, according to this criterion, nothing is requiſite but to obſerve the lightneſs of the colour, and the depth of the light-coloured *ſtratum*, after it has been expoſed to the air for a given time. In caſes in which the blood is unuſually black, and but little affected by common air, it ſhould ſeem, that breathing a purer air might be preſcribed with advantage.

In general, the blood that I have been able to procure in the city has not been ſo good as that which I have got in the country; owing, perhaps, to the cattle having been much driven, and heated before they were killed.